Problems Guide

AST 101 Solar System

for the West Campus lecture classes of Dr. Gary Mechler

Though the level of math used in this course is only first-year algebra, and the assigned problems solvable in only one or two stips, a sizable portion of students have trouble figuring their way through the problems and don't even try them or, if they do, can write nothing down. I don't want you to lose a learning opportunity here. One of the Greek contributions to science and learning in general was mathematics. It is essential to your success and powerful. The modern technologies upon which we all depend would be impossible without mathematics. By succeeding in doing these problems, you will be more aware of how we can make specific predictions, and that is the essential practical use of scientific understanding—to predict.

Not all problems assigned involve calculation, but I will still give you some helpful hints for them, for example, the very first problem assigned at the end of Chapter 2. Assignments not mentioned have no problems in them.

Assignment 1

Chapter 2, Problem 9 (first part only): In reading the chapter, don't ignore the illustrations and their captions. The key to answering this problem is in one of those. OR, you can "get real" and go outside this evening and find Polaris, the north star, and estimate its altitude (0° at the horizon; 90° at the zenith).

Assignment 2

Chapter 4, Problems 5-7: You need to know just three things to solve these problems. Kepler's Third ("Harmonic") Law, $P^2 = a^3$, and what is meant by the Period (P) and semi-major axis (a). Particularly, remember the semi-major axis is simply what it says: half the major axis. This is a hint for solving Problem 6.

Problems 5 and 6 require you to solve Kepler's Third Law for P. To do this you first take the square root of both sides of the equation. (Remember, equation means both sides are equal; you can't mess with one side without doing the same messing to the other.) The square-root is the inverse operation of the square. Inverse operations are those that cancel out. When roots are written as exponents, they appear as fractions. That is, something-squared has an exponent of 2; the square-root of something shows that something having an exponent of ½. So, when you take the square root of both sides of the Third Law equation, it looks like $P = a^{3/2}$.

In Problem 7, we need to calculate the semi-major axis, given the orbital period. Use the reasoning above to solve the Third Law for a this time, instead of for P.

Assignment 3

Chapter 5, Problem 1: Check your notes on this. I went over this in class–or will very soon. Because this problem is only a comparative one (i.e. one situation compared to another), we are applying the same Newton's gravity equation to two different situations. To calculate the ratio of one gravity strength to another, we take the ratio of the same equation, but *noting only the factors that change*. The gravitational constant, *G*, is, well, constant, so it doesn't change. And both situations involve the same object (so same mass) in the vicinity of Earth, whose mass doesn't change, either. The only factor that does change is what? Yes, the distance. And how does the force of gravity vary with distance? $F_g \propto 1/d^2$. Substitute in the ratio between the two relevant distances and solve.

Let's apply this here with another example. Let's use an example with a real-world aspect. How strong is the Earth's gravitational pull at the moon's average distance compared to its pull at the Earth's surface? Remembering from Hipparchus, the moon's average distance is 30 Earth radii. So, the ratio of the gravitational pull of Earth at 30 Earth-radii distance to its pull at its surface is $1/(30/1)^2$, which equals 1/900 or 0.00111.

Problem 2: This is a comparative calculation—the moon's surface gravity compared to the earth's. This means you will take the formula for gravity, applying the appropriate quantities to the moon, and divide it by the same formula, but with quantities for the earth substituted in. Look at Newton's gravity equation. The first term is the constant of proportionality, *G*, that makes the *relation* ($\propto$) between gravity and size and mass an *equality* (=). Is there a *G* for the moon that's different from the one for earth? NO! It's a CONSTANT! So it simply cancels out in the division *G/G* = 1. How about the masses and sizes? Well, they're different. Here you have to look up the numbers and substitute them into your equation. Divide the masses (same thing as getting the ratio) and divide that ratio by the ratio of the sizes squared. But what's the size, you ask? Zero distance, because you're standing on the surface? No, you use the distance from you to the average location of all the mass of the object you're standing on and that average location is the center (of the moon, earth, whatever you're standing on). That distance, of course, is the radius. So find the radii of the earth and moon, obtain their ratio, then square it and divide into the mass ratio. Remember, you are comparing the moon's surface gravity to the earth's, so you are dividing the moon's properties by the earth's properties, not the other way around. We will be learning this sort of calculation in the "Surface Gravity" lab activity.

Assignment 5

Chapter 1, Problem 1: This is a conversion problem. "You need more little units (or fewer larger units) to express the quantity of something." For our students who come from a country other than the United States and, hence, are used to dealing with an intelligent measurement system, I will help you by pointing out that there are 12 inches in one foot. Three feet in one yard. And 5,280 feet in one mile. Gad, how awkward and 'off-the-wall', but we're too resistant to change to the metric system completely, yet.

Problem 2: This is another conversion problem. "You need more little units (or fewer larger units) to express the quantity of something." You're given the conversion factor. Just do it.

Problem 5: This is a problem of proportions. Since the speed of light is constant, the ratio in time (moonlight/sunlight) is simply proportional to the ratio in how far the light must travel—the distance, moon/sun. Use the Planet Properties table on the inside back cover to get the sun's distance you need and, ever helpful, I will direct you to the Moon's "Celestial Profile"on p. 499 (9^{th} edition). You will notice these data files at the start of each chapter or section dealing with a major solar system object. Finally, take advantage of understanding that the moonlight/sunlight time-ratio will be in the same proportion to the distance ratio; that is, set the two ratios equal to one another and solve for the time needed for sunlight to reach Mars. (It's the same light speed for both, right?) Ignore orbital eccentricities; just use the semi-major axis values.

Problem 6. Conceptually similar to Problem 5 and uses info from it—the time for light to reach us from the sun. And the moon's distance is what, compared to the sun?

Chapter 19, Problem 4: Scary looking, but actually is easy as 1-2-3. To age-date a rock, the first step is to assess the rock in the lab to determine the fraction of original radioisotopes still remaining (= current # / original #). You can straightforwardly determine this fraction from the numbers the problem gives for the current radioisotopes relative to (ratio!) the original quantity. Determining that fraction is the first step. The second step is to answer the question, "How many half-lives of decay has this meteorite had to experience to result in the fraction we determined in step 1 for the original radioisotopes still remaining?" For that, use the decay graph you noticed when you read the chapter, Figure 19.6 in the 10^{th} edition. (You have read the assigned parts of the chapter, right?) Now, armed with the number of half-lives the meteorite has existed, step 3 is obvious. To age-date in absolute units (years, in this case), just multiply the number of years needed to decay one half-life (You'll find that time in the chapter.) times the number of half-lives you got in step 2.

Problem 5: This is straightforward except for the confusion on the part of some students to go to Figure 19-2. The problem requires Table 19-2, as is stated. You make your deductions from the numbers given in the table. There is no actual calculation here, just number comparing and drawing an inference.

Assignment 6N

Chapter 25, Problem 12: Don't hyperventilate. It's just a two-step problem. The first step is to calculate the total mass from the information given, mass/nucleus times # of nuclei. Notice how the nuclei units cancel out, leaving only the unit of mass, kilograms in this case.

The second step is to use the #kg/Earth mass. Conversion problem; already gave hints above, but from doing the first step to this problem, you now see another way to see your way through a proper conversion—apply the conversion factor in such a way as to see the unit you are calculating *from* cancel out, leaving only the unit you are converting *to*, in this case, Earth masses.

Chapter 3, Problem 3: This is not conceptually difficult and historically most students haven't had much trouble with it except, for one little aspect. Their answers are almost always wrong. Why? They haven't read the chapter or the problem carefully enough. You should pick up from reading the chapter that there are *two* important ways of describing the orbital period of the moon. One way results from referring to the moon's positions relative to the distant, fixed stars. The *sidereal* period results from the stars as reference. And the other useful reference is the sun. The *synodic* period results from this. This is the period of the phases, right? (Because they result from the moon's direction with respect to the sun, not the stars.) With this in mind, you answer the question using the proper period, multiplying by the fraction of the orbit from 1^{st} to 3^{rd} quarter phase, and rounding off to the nearest integral number of days (because that's all the author is asking for).

Assignment 7

Chapter 20, Problem 3: This is a distance = rate x time problem. You could figure out the solution by noting what multiplication or division you need to get an answer in time units. ("Hpw long ago...?") To solve the above equation, which can be simply written as $d = rt$, you isolate t by performing the inverse operation (sound familiar?) on r. Of course, because this is an equation, you must perform the identical operation on the left hand side of the equation as well.

The one little complication to solving this problem is that the rate is so low, it involves the unit of cm (= 0.01 m), but the resulting distance is in km(= 1000 m). You need to convert one unit to the other, your choice. I leave it to you to calculate the actual factor between cm and km. Now, whether you multiply or divide by it depends upon which way you go. Are you going to the larger unit? Then, you will need fewer of them (and vice-versa).

Assignment 9N

Chapter 22, Problem 1: Well, I already give the needed hints on the pink Assignment Sheet. But I can give you a further hint here that will get you past an initial sticking point of figuring out what the distances are: First, visualize the positions in space that Venus, sun, and Earth must have when Venus is closest and then farthest away. Go ahead and draw the sun with the planets in their respective orbits. In the recent Mars Lab, you were acquainted with the positions of the planets in their orbits when they are closest and farthest from one another. Then get the semimajor axis values from the Planet Properties table (at very back of book) to get the distances you need to determine the minimum and maximum distances of

Venus from Earth.

Further hints: The appropriate unit of distance is km, not AU. Don’t forget that the time you are to determine is for there and back. Convert your answer to minutes and seconds. Just showing the answer in gobs of seconds isn’t astute.